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Short-Eared Owl Post-Fledging Survival and Breeding Season Diet

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SHORT-EARED OWL POST-FLEDGING SURVIVAL AND BREEDING SEASON DIET

by

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ABSTRACT

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Utah State University, 1998

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My research primarily focused on the survival of short-eared owls (Asio flammeus) from leaving the nest until their emigration from their natal territories during 1993 and 1994. I attached tarsal-mounted radio transmitters to nestlings prior to fledging. Of 25 fledgling short-eared owls monitored, 16 (64%) died prior to dispersal and one (4%) died after dispersing. Mammalian predation (5, 29.4%) was the primary cause of mortality followed by starvation (4, 23.5%), exposure (2, 11.8%), auto collision (1, 5.9%), burial (1, 5.9%), and unknown causes (4, 23.5%). Hatch date was found to be negatively correlated with fledgling survival.

A secondary focus of my research was the breeding season diet of short-eared owls based on the identification

of 704 prey items. The diet was dominated by small mammals (98.4%), primarily Great Basin pocket mice (Perognathus parvus, 33.8%), deer mice (Peromyscus maniculatus, 31.1%), Ord's kangaroo rats (Dipodomys ordii, 12.8%), and mountain voles (Microtus montanus, 12.5%). A significant change in prey proportions was observed between 1993 and 1994 and also with distance from the nesting site to irrigated agricultural land.

During 1994, I evaluated a mist net technique for capturing adult short-eared owls during the breeding season, capturing seven adults in 25 attempts.

(74 pages)

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Thomas A. Rivest

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CHAPTER I

INTRODUCTION

The short-eared owl (Asio flammeus) is a medium-sized, sexually dimorphic owl with a mass of approximately 378 g for females and 315 g for males. A long-winged owl of open areas, short-eared owls spend more time on the wing than most owls with hunting, courtship, and territorial activities often taking place while flying (Mikkola 1983, Johnsgard 1988, Holt and Leasure 1993). Sexually dimorphic plumages allow most pairs to be sexed visually during the breeding season. Females tend to be darker brown dorsally and darker rust ventrally than the males, which are often light cream color underneath. Juveniles, with a brown-black facial disc, during their first summer are even darker rust colored ventrally and darker brown dorsally than the females and can be identified in the field.

One of the most widespread owls in the world, short-eared owls occupy, for at least part of the year, all of the continents except Antarctica and Australia. Occupying North America, Europe, and Asia is the single subspecies Asio flammeus flammeus with a circumpolar holarctic distribution (Mikkola 1983). At least seven other subspecies occupy parts of South America and various oceanic island groups such as Caroline, Falklands, Galapagos, Greater Antilles, Hawaiian, and Micronesia Islands (Mikkola 1983, Holt and Leasure 1993). The short-eared owl occasionally winters in

northern Africa but is replaced as a breeding species throughout much of Africa by the closely related African marsh owl (Asio capensis, Mikkola 1983). In North America, this species breeds north of approximately 37° N to the Arctic ocean where suitable open habitat exists (Johnsgard 1988, Holt and Leasure 1993).

One of only nine species out of the 151 species of owls existing worldwide that nest regularly on the ground, the short-eared owl is found in open habitats with low grassland or shrub vegetation such as marshes, pastures, prairie lands, heathlands, tundra, and shrubsteppe habitats (Johnsgard 1988, Hume 1991). The short-eared owl is one of the few owls which constructs its own nest; most others species reuse raptor or other large bird nests, or nest in cavities (Hume 1991, Holt and Leasure 1993). Nesting areas may be occupied in consecutive years but usually by different individuals with the nest scrape located in a different spot each season (Holt and Leasure 1993). Nests and incubating female short-eared owls are usually well concealed by surrounding vegetation. Nests are very difficult to locate due to the cryptic coloration of the female and her behavior: females often refuse to flush off the nest until approached within 1-2 m (Tate 1992).

Short-eared owls are a nomadic species breeding when their main prey, small (10-200 g) mammals, are abundant

(Mikkola 1983, Johnsgard 1988, Holt and Leasure 1993). Across large portions of North America, voles (Microtus sp.) are the dominant prey item in the diet of the short-eared owl (Holt and Leasure 1993). A strong positive correlation between the spring population density of Microtus sp. and the number of nesting short-eared owls was found in western Finland. The number of breeding pairs fluctuated between 0 and 49 pairs and the mean number of young produced ranged from 0 to 4.1 per breeding pair over a 10-year study period (Korpimäki and Norrdahl 1991).

Worldwide, the short-eared owl population is considered to be stable at this time; however, in certain areas populations are declining. In Northern Europe, where the short-eared owl is a regular breeder, there is no evidence of any population changes. In Britain, numbers have steadily increased as the number of coniferous plantations have increased; these plantations provide excellent grassland habitat while the trees are small. However, in central Europe, the short-eared owl has vanished as a breeder from many areas due to habitat loss as a result of cultivation and water-level management programs (Mikkola 1983). In North America, the short-eared owl is threatened where its open habitat is being altered due to changes in land use patterns (Holt and Leasure 1993). Also some otherwise suitable habitats may be rendered unsuitable due

to increased predation risk from humans and domestic pets. The short-eared owl was on the Audubon Society's Blue list of declining species from 1976 to 1986 when the list was discontinued (Johnsgard 1988). Currently, in the northeastern United States, the short-eared owl is listed as either endangered, threatened, or of special concern in 7 of 13 northeastern states where it has suffered significant habitat losses (Tate 1992, Holt and Leasure 1993). In the midwest where this species may have never been abundant, the short-eared owl is listed as a species of special concern in all states except Minnesota. It also has been recently listed as a species of special concern in California and Utah. In most of the northwest mountain states, northern plains states, and western Canadian provinces, populations are viewed as being stable in size (Tate 1992, Holt and Leasure 1993).

In terms of long-term species survival, it is important to maintain a species distribution throughout its existing range (Verner 1992). Much of what we know about short-eared owls comes from studies of Asio flammeus flammeus in mesic environments in the northern hemisphere. Few data are available either for xeric habitats or other short-eared owl populations (Holt and Leasure 1993).

In order to predict changes in population size that occur as the result of natural or human-induced

environmental changes, knowledge of primary demographic parameters such as fecundity and mortality is required (Ricklefs 1973). Studies of lifetime reproductive success indicate that post-fledgling survival and reproductive life span are the major contributors to the observed variance in lifetime reproductive success (Newton 1989, Saurola 1989, Sullivan 1989). Little information is available on post-fledgling survival (Newton 1979, Sullivan 1989, McFadzen and Marzluff 1996, Anders et al. 1997) and thus many studies assume post-fledgling survival equals annual adult mortality. However, the required assumption of stable population size may not apply to threatened populations. Alternatively, post-fledgling survival can be estimated through the observed ratio of juveniles to adults, if adult survival is known (Ricklefs 1973). This approach is unsuitable for short-eared owls, where the juveniles lose their distinctive plumage in late summer and adult survival rates are poorly understood (Holt and Leasure 1993). The direct measurement of post-fledgling survival for short-eared owls is required to gain a better understanding of their true reproductive success and population status.

Taylor (1994) found three factors responsible for changes in the number of breeding barn owls (Tyto alba): adult survival rate, survival rate of first year birds, and the rate of recruitment of birds of all ages into the

breeding population. All of these factors cycled with prey density. To accurately interpret post-fledgling survival and nesting success of short-eared owls, an understanding of their breeding season diet is necessary. While the nonbreeding season diet for short-eared owls is the most well documented aspect of its biology, the breeding season diet is less well known and then only in mesic habitats (Holt and Leasure 1993).

To better understand short-eared owl population dynamics in the widespread xeric shrubsteppe habitat of the western United States, I examined the breeding season diet and post-fledgling survival of short-eared owls in southwest Idaho. The study, conducted during 1993 and 1994, took place largely at the Snake River Birds of Prey National Conservation Area (NCA). This study, part of a larger multiyear study examining the effect of military training on raptors at the NCA, was confined to the benchlands north of the Snake River Canyon within the 198,616 ha Integrated Study Area (ISA, U.S. Dept. of Interior 1996).

The study area is a relatively flat shrubsteppe terrain with isolated buttes. The climate is relatively mild in the winter with a daily average January temperature in nearby Boise of -1° C and most of the precipitation occurs between November and April. The summers are hot and dry; the daily

average July temperature in Boise is 24° C. Annual precipitation ranges from 15 to 25 cm in the NCA. Native shrublands were dominated by big sagebrush (Artemisia tridentata), winterfat (Krascheninnikovia lanata), and shadscale (Atriplex confertifolia), along with native perennial bunchgrasses such as bottlebrush squirreltail (Elymus elymoides) and Sandberg's bluegrass (Poa secunda). Exotic grasses and forbes such as cheatgrass (Bromus tectorum), Russian thistle (Salsola kali), and various mustards (Sisymbruim spp., Descurainia spp.) now cover over half of the study area (U.S. Dept. of Interior 1996). Short-eared owls use the NCA both as a wintering and breeding area. The number of occupied short-eared owl nesting territories located in 1993 and 1994 were 11 and 35, respectively (Lehman et al. 1998).

To study the breeding season diet, I collected regurgitated pellets of undigestible prey remains such as fur, feathers, and bones from occupied nesting territories as encountered while conducting a short-eared owl post-fledgling survival study. A total of 704 prey items were identified. In Chapter II of this thesis I report my findings on the breeding season diet of short-eared owls. To examine short-eared owl post-fledgling survival I radio-instrumented 25 nestling owls at approximately 12 d post-hatching and then monitored their survival and identified

the causes of mortality. In Chapter III of this thesis I report the findings of the survival study.

I applied a mist net technique (Steenhof et al. 1994) to capture breeding adult short-eared owls in the study area. In Chapter IV of this thesis I describe this trapping method and its performance in capturing territorial adult short-eared owls.

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CHAPTER II

BREEDING SEASON DIET OF SHORT-EARED OWLS IN SHRUBSTEPPE HABITAT OF IDAHO

ABSTRACT.--I examined the breeding season diet of short-eared owls (Asio flammeus) in xeric shrubsteppe habitat in southwestern Idaho during 1993 and 1994. A total of 704 prey items were classified, with 98.4% being small mammals, primarily Great Basin pocket mice (Perognathus parvus, 33.8%), deer mice (Peromyscus maniculatus, 31.1%), Ord's kangaroo rats (Dipodomys ordii, 12.8%), and mountain voles (Microtus montanus, 12.5%). Prey proportions varied significantly between 1993 and 1994 and also with distance from the nesting site to irrigated agricultural land.

INTRODUCTION

One of the most widespread owls, the short-eared owl (Asio flammeus) occurs in open habitats from temperate grasslands, marshes, and shrubsteppe to arctic tundra across the holarctic and into South America. With such a wide range of occupied habitats, it is important not to base our understanding of the ecology of the short-eared owl on studies conducted in a single habitat type. Reproductive success and population dynamics are closely linked with prey density (Holt and Leasure 1993). Management and protection

plans for this wide-ranging species require dietary information from a variety of habitats.

Analysis of regurgitated pellets of indigestible prey remains such as bones, fur, and feathers is a widely used and excellent dietary analysis technique for medium-sized owls such as short-eared owls (Marti 1987). Numerous studies have examined short-eared owl diets during the nonbreeding season (review by Holt 1993b). In contrast, only a few have examined the breeding season diet (Clark 1975, Holt and Melvin 1986, Wiebe 1991, Holt 1993a). All of the previous diet studies occurred in mesic habitats where Microtus spp. were usually the dominant prey species (Holt 1993b). In contrast, this study examines the breeding season diet in a xeric shrubsteppe habitat; useful information to biologists and land managers responsible for managing this wide-ranging sensitive species.

METHODS

The study site was the upland plains north of the Snake River in the 198,616-ha Integration Study Area within the Snake River Birds of Prey National Conservation Area (NCA). The NCA is located within three southwestern Idaho counties: Ada, Elmore, and Owyhee. The characteristics of this semiarid shrubsteppe study area have been described in detail elsewhere (U.S. Dept. of Interior 1996). Field work occurred from mid-March to late August during 1993 and 1994.

Pellets were collected from roost and nest sites as encountered while performing other research activities. I sampled 7 nesting areas in 1993 and 16 in 1994, with each area visited one to four times per year. Pellets collected during all visits throughout the year within a nesting area were lumped together as a single sample. Each nesting area contained at least one adult short-eared owl, usually a pair and their offspring for that breeding season, up to a maximum of eight owls. Pellets from both adult and young owls were included in the sample. I classified pellets as weathered if they exhibited erosion of hair from bones and a bleached appearance. All other pellets were classified as recent. I assumed that weathered pellets were produced prior to the current breeding season as most of the precipitation occurs between November and April (U.S. Dept. of Interior 1996). Weathered pellets could be from the previous breeding season or from overwintering birds. Raptor pellets generally decompose within one year in a unprotected locations (Marti 1987). Northern harrier (Circus cyaneus) pellets were excluded from the sample using techniques described by Clark (1972) and Holt et al. (1987). Although long-eared owls (Asio otus), burrowing owls (Athene cunicularia), and occasionally great horned owls (Bubo virginianus) occur near short-eared owl nesting areas, these

birds were usually excluded by territorial adults from the immediate vicinity of the nest and roost sites.

Dry pellets were teased apart by hand to isolate bones, hair, and feathers. The number of mammalian prey items per pellet was determined by counting the number of skulls and/or mandibles. Mammalian prey were identified to species when possible (Glass 1973). Posterior portions of larger prey skeletons such as Dipodomys spp. found in pellets were counted as separate individuals if no skulls were found in other pellets within that sample. Avian prey were quantified by counting sterna or maxilla. Any prey remains found in the nest or at roost sites were identified using field guides and included in the sample. Prey items from pellets broken during handling in the field or during transport from the field were not included in prey per pellet calculations.

For biomass calculations a mean prey mass of 81.5 g was assigned to chisel-toothed kangaroo rat (Dipodomys microps; Burt and Grossenheider 1976). The following mean prey masses are from Steenhof (1983): Great Basin pocket mouse (Perognathus parvus) 17 g, deer mouse (Peromyscus maniculatus) 19 g, Ord's kangaroo rat (Dipodomys ordii) 53 g, mountain vole (Microtus montanus) 35 g, Western harvest mouse (Reithrodontomys megalotis) 11 g, Townsend's ground squirrel (Spermophilus townsendii) 176 g, and horned lark

(Eremophila alpestris) 26 g. The mean prey mass for the unidentified Dipodomys spp. category was assumed to be the same as Ord's kangaroo rat. The mean prey mass for the unidentifiable small rodent category was the average of the Great Basin pocket mouse, deer mouse, and Western harvest mouse prey masses.

Food niche breadth was calculated using the antilog of the Shannon-Wiener diversity index (Marti 1987).

RESULTS

I classified a total of 704 individual prey items. Of these, 439 prey items were from pellets classified as recent, representing the breeding season diet. The other 265 prey items were from weathered pellets of uncertain vintage. Examination of 256 unbroken pellets uncovered 576 prey items (mean = 2.25 prey items/pellet). Small rodents accounted for 98.4% of prey items. Two species, Great Basin pocket mouse and deer mouse, numerically made up 33.8 and 31.1%, respectively, of the prey items identified. Most of the remaining small rodents were either Ord's kangaroo rat (12.8%) or mountain vole (12.5%). Some small rodents and Dipodomys spp., which could not be identified due to incomplete dentition or skulls, represented 3.7% and 3.0%, respectively, of the diet. The remaining mammalian prey included western harvest mouse (1.0%), Townsend's ground squirrel (0.4%), and chisel-toothed kangaroo rat (0.1%).

Avian prey (0.85%) represented a very small portion of the total sample. A horned lark was the only one of six avian prey items that could be identified. Small insect exoskeleton fragments were found in five pellets, representing 0.7% of prey items. The top four species, in terms of biomass, were Ord's kangaroo rat (26.0%), deer mouse (22.8%), Great Basin pocket mouse (22.1%), and mountain vole (16.8%). The next three most important prey categories in terms of biomass were unidentified Dipodomys spp. (6.1%), Townsend's ground squirrel (2.9%), and unidentified rodent spp. (2.2%). Western harvest mouse and chisel-toothed kangaroo rat each contributed 0.4% to the total diet biomass. Food niche breadth was calculated to be 5.14.

Diet composition by year is shown in Table 1. The 1993 sample consisted of 40 prey items from 28 whole recent pellets (mean = 1.43 prey/pellet) and 4 prey items from broken recent pellets. From weathered pellets in 1993, 213 prey items were found in 112 whole pellets (mean = 1.90 prey/pellet) and 52 prey items were found in broken pellets. The 1994 sample contains 323 prey items from 116 whole recent pellets (mean = 2.78 prey/pellet) and 72 prey items from broken recent pellets. During 1994 only recent pellets were collected. All prey/pellet mean comparisons differed significantly (ANOVA [Student-Newman-Keuls test post hoc

test, $P < 0.05$] $F_{(2,253)} = 23.29$, $P = 0.0001$, Appendix, Table A1). Examining the four most common prey species, deer mouse, Great Basin pocket mouse, mountain vole, and Ord's kangaroo rat, a significant shift in prey proportions was observed between the 1993 and 1994 samples of recent pellets ($\chi^2 = 135.8$, df = 3, $P < 0.001$). More deer mice and fewer Ord's kangaroo rats were consumed in 1994 compared to 1993. This shift was still significant when recent and weathered pellets from 1993 were combined and compared with the 1994 pellets ($\chi^2 = 288.9$, df = 3, $P < 0.001$). By combining all samples from both years, significantly fewer deer mice and more Ord's kangaroo rats, Great Basin pocket mice, and mountain voles were consumed at nesting areas within 500 m of irrigated agricultural land ($\chi^2 = 137.7$, df = 3, $P = 0.001$). There were insufficient data to examine the relationship between prey selection and location for each year separately.

DISCUSSION

The high percentage of mammalian prey, 98.4%, in the diet of short-eared owls in this study is consistent with previous studies. In three breeding season and nine nonbreeding season studies reviewed by Holt (1993b), the percentage of mammalian prey in the diet ranged from 79.4% to 99.8%, dropping below 95% in only two studies. This is

the first study to report such a large Food Niche Breadth (5.14) in a short-eared owl diet almost exclusively composed of mammalian prey. Most other largely mammalian short-eared owl diets have reported Food Niche Breadth's of 1.14 to 2.69 (Holt 1993b). In most earlier studies short-eared owl diets were dominated by Microtus spp., which comprised 42.5 to 97.2% of mammals consumed (Holt 1993b). In my study area, the only Microtus species, mountain vole, is restricted to the relatively scarce, irrigated agricultural and riparian sites (Montan 1977). Short-eared owls apparently switch to the smaller but more abundant and widespread Great Basin pocket mouse and deer mouse (Montan 1977) in xeric areas where Microtus species are scarce.

The data presented here are very similar to the results of a dietary study of the closely related long-eared owl, conducted within roughly the same study area (Marks 1984). The same four prey species that dominate the diet of short-eared owls in this study dominated the diet, although in different proportions, of breeding long-eared owls (Marks 1984). Like the long-eared owl study, nest sites varied with respect to the dominant prey species in my study, with Ord's kangaroo rat the most common prey at three sites, Great Basin pocket mouse at five sites, mountain vole at five sites, and deer mouse at nine sites.

The change in prey proportions and prey per pellet between study years probably reflects changes in prey populations. In 1994 short-eared owls consumed fewer Ord's kangaroo rats, a large prey species, and more deer mice, a small prey species, than in 1993, resulting in a higher prey/pellet ratio in 1994. The number of occupied short-eared owl nesting areas increased from 11 to 35 between 1993 and 1994 (Lehman et al. 1998). Although I do not have any direct data on prey populations for 1993 or 1994, short-eared owl populations are synchronized with prey population cycles (Korpimki 1984) and thus it is likely that the increase in the number of breeding pairs of short-eared owls was due to an increase in prey population levels in one or more of the four most common prey species. Species density and composition of desert rodent populations have been shown to increase after increased precipitation and the resulting increase in vegetation (Whitford 1976, Munger et al. 1983, Keller 1989). Additionally, Whitford (1976) reported a 10-12 month lag time in the numerical response of various rodent species populations after favorable rainfall levels, except for deer mice, which had only a 6 month lag time. This could explain the increased occurrence of deer mice in the short-eared owl diet observed in this study. Examining bioyear precipitation of 1993 and 1994, 1993 was wetter than normal and 1994 was substantially drier than normal.

Bioyear precipitation is the rainfall between November and April, when most of the plant growth in my study area occurs (U.S. Dept. of Interior 1996).

The effect of distance to irrigated agricultural lands on prey items selected is possibly due to the relative abundance of the four most common prey species at mesic and xeric sites. Earlier research reported that deer mice were most common in big sage (Artemisia tridentata) ecotones, whereas both mountain voles and Ord's kangaroo rats had higher densities along range-agricultural ecotones. Ord's kangaroo rats were possibly attracted to agricultural land because the disturbed soil along roads around farms provided favorable burrowing conditions (Montan 1977). However, it is also probable that prey proportions near agricultural land are affected by unequal prey vulnerability of the various prey species. Bechard (1982) reported vegetative cover was more important than prey density in the selection of hunting areas by male Swainson's hawks (Buteo swainsoni). Most of the agricultural land near short-eared owl nesting areas was planted in alfalfa (Medicago sativa), which was periodically harvested during the breeding season, exposing the resident mountain voles to increased predation risk. The increased availability of mountain voles and low vegetative cover for Ord's kangaroo rats along dirt roads

are likely partly responsible for the shift in prey proportions near agricultural land.

This study has shown that short-eared owls specialize on 10-200 g rodents rather than the more exclusive group of microtine rodents. Short-eared owls exhibit generalist behavior, switching mammalian prey species as prey population levels and availability change both spatially and temporally. This is a complex system, with multiple prey species responding at different rates to changes in environmental parameters such as precipitation.

Further study is needed to determine the prey conditions that lead to successful short-eared owl breeding in xeric environments. Is it the prey density of one particular species or the total prey density that is the decisive factor? It is also important to understand the relationship between xeric plant communities and prey density and availability during both relatively wet and dry years. Such information would aid land managers in managing vegetation to provide optimum breeding habitat for short-eared owls and their prey species. In my study area, fires (both human and lightning caused), livestock grazing, and conversion of land to agriculture are the primary agents of change to native plant communities and all can be managed to some extent. Managing the vegetation for optimum prey levels is a more cost effective strategy than trying to

annually monitor breeding success for short-eared owls. This is especially true in a xeric habitat where moisture, resulting prey, and short-eared owl breeding population levels are highly variable year to year. This study, which demonstrates the relative complexity and annual variability of this short-eared owl/prey system, can be used as a foundation for further study.

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Table 1. Short-eared owl prey sample by year.

Species	1993 weathered	1993 recent	1994 recent
Mammals			
Great Basin pocket mouse (Perognathus parvus)	140 (52.8%)	13 (29.5%)	85 (21.5%)
deer mouse (Peromyscus maniculatus)	26 (9.8%)	6 (13.6%)	187 (47.3%)
Ord's kangaroo rat (Dipodomys ordii)	75 (28.3%)	13 (29.5%)	2 (0.5%)
mountain vole (Microtus montanus)		1 (2.3%)	87 (22.0%)
unidentified rodent spp.	2 (0.5%)	2 (4.5%)	22 (5.6%)
unidentified Dipodomys spp.	11 (4.2%)	7 (15.9%)	3 (0.8%)
western harvest mouse (Reithrodontomys megalotis)	4 (1.5%)		3 (0.8%)
Townsend's ground squirrel (Spermophilus townsendii)		1 (2.3%)	2 (0.5%)
chisel-toothed kangaroo rat (Dipodomys microps)			1 (0.3%)
Birds			
unidentified bird species	4 (1.5%)		1 (0.3%)
horned lark (Eremophila alpestris)		1 (2.3%)	
Insects			
unidentified insect species	3 (1.1%)		2 (0.5%)
Total prey items	265	44	395

CHAPTER III

SHORT-EARED OWL FLEDGLING SURVIVAL IN SOUTHWESTERN IDAHO[1]

ABSTRACT.--I monitored the survival of 25 fledgling short-eared owls during 1993 and 1994 in southwestern Idaho. Sixteen (64%) fledglings died prior to dispersing from their natal territories and one (4%) died after dispersing. The causes of mortality were mammalian predation (5, 29.4%), starvation (4, 23.5%), exposure (2, 11.8%), auto collision (1, 5.9%), buried (1, 5.9%), and unknown causes (4, 23.5%). Fledgling survival was negatively correlated with hatch date.

INTRODUCTION

The survival rate of fledglings is an important component of avian population dynamics (Ricklefs 1973, Perrins and Birkhead 1983, Newton 1989, Sullivan 1989). Due to the difficulty of directly measuring survival during this period, many studies assume a stable population and estimate fledgling survival from adult annual mortality (Perrins and Birkhead 1983). These estimates do not provide adequate information for studying the population dynamics of threatened or sensitive species where variation in fledgling survival may contribute to changes in the species population size.

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[1]Coauthored by Thomas A. Rivest and Dr. Kimberly Sullivan.

The short-eared owl (Asio flammeus) is a widespread owl with a circumpolar holarctic, discontinuous South American, and isolated island distribution (Mikkola 1983). It nomadically occupies open habitats such as grasslands, shrubsteppe, tundra, and marshes in response to the abundance of its main prey, small mammals (Holt and Leasure 1993). In North America, the short-eared owl was on the Audubon Society's Blue List of declining species from 1976 until the list was discontinued in 1986 (Johnsgard 1988). More recently, the short-eared owl was designated a species of special concern in Utah, California, and most of the midwest states. Northeastern populations are even more imperiled with the short-eared owl listed as: endangered in Massachusetts, Pennsylvania, and New Jersey; threatened in Connecticut; and a species of special concern in Maryland, New York, and Vermont. Only in the northern Great Plains and northwest states are populations of this species viewed as being stable (Tate 1992, Holt and Leasure 1993). Nest predation and land use changes are an important component of the population dynamics of this ground-nesting species and these factors may profoundly affect its distribution and abundance (Mikkola 1983, Holt and Leasure 1993).

Nesting success, being easier to directly measure in raptors than the survival of adults or fledglings, is often used as an index of population status (Steenhof 1987). In

contrast to the monitoring of a stationary nest, measurement of post-fledgling survival requires marking individuals, relocating them, and determining when they die. Basing population estimates on the recovery of previously banded individuals requires a prohibitively large sample size for wide-ranging secretive raptor species with low band return rates (Young and Kochert 1987). Consequently, land managers use nesting success studies to monitor short-eared owl population dynamics.

In nesting studies it is desirable to measure success as close to fledgling as possible to obtain accurate estimates of the number of young produced. In addition, disturbance early in the nesting season can contribute to nest failure as some raptors will abandon a nest if disturbed during egg laying, early incubation, or hatching (Steenhof and Kochert 1982). But visits to measure nesting success close to fledging age puts the nestlings at risk from forcible early fledging. For diurnal raptors, a successful nesting attempt is commonly defined as one or more young reaching 80% of the mean fledging age. Fledging age in diurnal raptors is defined as the age at which young raptors leave the nest by taking their first flight. Mortality between 80% of fledging age and the actual fledging date is assumed to be minimal (Steenhof and Kochert 1982, Steenhof 1987, but see Marzluff and McFadzen 1996).

For owls, measuring nest success as the number of young reaching 80% of mean fledgling age is often unreliable because in many species the young leave the nest long before taking their first flight (Forsman et al. 1984). Short-eared owls leave the nest as young as 12 d post-hatching and then spend 2 to 3 weeks concealed in ground cover up to 175 m away from the nest before their first flight (Clark 1975, Holt and Leasure 1993). It is unknown whether the number of young alive 12 d post-hatching is an accurate estimate of nesting success in short-eared owls.

Radio-telemetry of nestlings and fledglings has been used successfully on a wide variety of avian species to directly determine both nesting success and juvenile survival (Belthoff and Ritchison 1989, McFadzen and Marzluff 1996, Rohner and Hunter 1996, Anders et al. 1997). I used radio-telemetry of juvenile short-eared owls to examine three questions: 1) What is the extent of mortality between 12 d post-hatching (the age when young begin to leave the nest) and dispersal from the natal territory? 2) What are the primary causes of short-eared owl mortality during the fledgling period? 3) Are short-eared owl brood sizes at 12 d post-hatching a significant predictor of the number of young alive at 20 d post-hatching, the age corresponding to 80% of the mean age of first flight?

METHODS AND STUDY AREA

The study site was located within three southwestern Idaho counties: Ada, Elmore, and Owyhee. The characteristics of this semiarid shrub steppe study area, located north of the Snake River in the 198,616-ha Integration Study Area within the Snake River Birds of Prey National Conservation Area (NCA), have been described in detail elsewhere (U.S. Dept. of Interior 1996). Field work occurred from mid-March to late August during 1993 and 1994.

The presence of breeding short-eared owls was detected using quadrat surveys, historical nest checks, or through incidental observations during field work. Nests were located by observing male short-eared owl courtship flights at dusk, which usually were centered over the actual nest site. Survey crews of one to four observers walked parallel transect lines 5 to 20 m apart, depending upon vegetation density, during daylight hours in the area of the courtship flights to locate the nest scrape.

Subsequent visits to the nest were made to determine the incubation and hatching schedule. If only a partial clutch (four eggs or less) was present on the initial visit, indicating an early stage of incubation, the nest would be revisited in approximately 3 weeks to determine if the eggs had begun to hatch. If a large clutch was present initially, the nest would be revisited after approximately

12 d. To minimize time spent at the nest scrape, egg development was not monitored by candling or other methods. To minimize predation risks from diurnal predators such as corvids, nest visits were made at dusk. Once eggs began to hatch, nestling age was estimated using descriptions of nestling development in Holt and Leasure (1993). For my study, owls younger than 13 d post-hatching were defined as nestlings. Those older than 12 d post-hatching and on their natal territory, whether they were in the nest or capable of flight, were defined as fledglings.

The original design was to attach radio transmitters to all nestlings in each nest when the oldest was approximately 12 d post-hatching. However, instrumenting all nestlings in large asynchronous broods (as many as nine nestlings) necessitated two or three visits to the nest to apply the radio transmitters as the legs of nestlings younger than 8 d post-hatching were too small to hold the transmitters. Nestlings were weighed, banded with a USFWS band on one leg, and equipped with a 6.5-g radio transmitter on the other leg. Transmitters were attached following the technique of McFadzen and Marzluff (1996). This is a relatively heavy transmitter for nestlings. Holt et al. (1992) reported a mean mass of approximately 160 g for nestlings 12 d post-hatching (n = 18). The transmitter mass corresponds to 4% of the body mass at that age, but by the time they actually

fly the transmitter mass should be well within the 3% of body mass limit recommended by the United States Fish and Wildlife Service (Hegdal and Colvin 1986). Earhart and Johnson (1970) report mean short-eared owl masses of $\bar{x}$ = 315 g for males (n = 20), and $\bar{x}$ = 378 g for females (n = 27), yielding transmitter mass to body mass percentages of 2.1% and 1.7%, respectively. Transmitters (Advanced Telemetry Systems, Isanti, Minnesota) contained a mortality circuit that doubled the pulse rate to 60 pulses per min if the transmitter remained stationary for more than 8 hr. Transmitters had a minimum guaranteed lifetime of 60 d.

I monitored the survival of radio-equipped young at 1- to 4-d intervals; however, access restrictions into the Idaho National Guard's Orchard Training Area sometimes prevented such frequent visits. Monitoring typically involved detection of the radio signal to determine the pulse rate of the transmitter. A slow pulse (30 pulses per min) indicated the fledging had moved within the previous 8 hr. Most visits to nesting territories occurred during late afternoon or at dawn to minimize midday disturbance. During every second or third visit, I used the radio signal to locate the owl for visual confirmation of survival. When I could no longer detect the radio signal of an instrumented juvenile short-eared owl, I expanded the search area to a diameter of approximately 8 km. Two subsequent visits were

made to the nesting territory, including a dusk watch to check for the continued presence of the breeding pair and the instrumented fledgling with a failed radio. I also scanned for radio signals while driving in the study area. If the instrumented owl or transmitter was not located during three visits, I classified that individual as having dispersed.

If a fatality was detected either through a transmitter pulse rate change or visual observation, the carcass was located and examined, and the probable cause of fatality was assigned. I grouped fatalities into six categories: mammalian predation, starvation, heat stress, buried, auto collision, and unknown. Detailed descriptions of these categories are provided in the results section.

Nest site habitat parameters were collected during a companion study (Lehman et al. 1994). I measured cover at 11 nest sites and 11 random points with a 1 m^2 coverboard covered with a 10 cm^2 checkerboard pattern. Additional short-eared owl nests, that failed prior to the young being instrumented, were included in the sample. Two sites with instrumented young (n = 9) were not included in the cover sample because the sites burned before cover measurements could be made. The random points were selected from a set of points, randomly placed throughout the entire study area, used as part of a parallel vegetation study. The coverboard

was placed in the nest after the young had dispersed. A count of the number of squares obscured was made in each of the four cardinal directions at a distance of 5 m from the coverboard and a height of 1 m. A mean value was then calculated for each nest site. All cover measurements were taken over a 10-d period in September after most vegetation growth had ceased.

Fledgling survival functions and covariates were analyzed using SAS® proc LIFETEST and LIFEREG. Proc LIFETEST calculated survivorship functions and confidence limits using the nonparametric Kaplan-Meier method as well as testing the null hypothesis of no relation of habitat parameters to survival. Parameters that showed potential influence on survival were then further analyzed using the more powerful parametric proc LIFEREG procedure (Allison 1995).

RESULTS

I monitored the survival of 25 fledgling short-eared owls from seven nests. In 1993, the sample consisted of two fledglings from one nest due to low numbers of breeding short-eared owls in the study area (Lehman et al. 1994). The sample in 1994 consisted of 23 fledglings from six nests. Eight (32%) fledgling short-eared owls successfully dispersed from their natal territories. Sixteen (64%)

fledglings died prior to dispersing from their natal territories and one (4%) died soon after dispersing.

The median age at which short-eared owls were instrumented was 11 d post-hatching with a range of 8 to 15 d. Broken down into two categories, fledgling owls which dispersed and those which died, the median age of instrumenting was 11 and 12 d post-hatching, respectively. The median age at dispersal was 54 d post-hatching with a range of 41 to 67 d. Among fatalities, the median age of death was 18 d post-hatching with a range of 11 to 48 d.

The fatalities were classified into the following categories: mammalian predation (5, 29.4%), starvation (4, 23.5%), heat stress (2, 11.8%), auto collision (1, 5.9%), buried (1, 5.9%), and unknown causes (4, 23.5%). All fatalities occurred in 1994 except for one unknown cause from 1993.

Examining the individual fatalities in detail reveals a wide variety of circumstances. Three of the mammalian predations occurred at one breeding territory within a single night. These short-eared owl carcasses were found within 223 m of each other, recovered at 200, 70, and 18 m from the nest scrape. Two carcasses were partially consumed and a third exhibited a single large puncture wound to the neck. Three surviving brood mates were located nearby. The other two mammal-caused fatalities occurred on a separate

breeding territory. These recently instrumented young owls, which had not left the nest yet, were found partially consumed and buried within 1 m of the nest. Canid tracks were found at the burial site. One entire brood (n = 4) of fledged short-eared owls starved to death after the adult female owl disappeared from the breeding territory. The adult male of this pair was radio instrumented and remained on the breeding territory. The four carcasses were recovered at 150, 850, 230, and 0 m from the nest scrape, ranked here by earliest to latest hatch date. Two fledgling brood-mates died from exposure. The carcasses were located in a short patch of cheatgrass (Bromus tectorum) within 15 m of the nest scrape, with no shade protection in the late afternoon when the air temperature had exceeded 38° C. One of the surviving brood-mates was brooded by the adult female, and the other was discovered inside an abandoned badger (Taxidea taxus) hole. One short-eared owl fledgling was discovered flattened approximately 300 m from its nest scrape, after apparently being crushed by a vehicle inside a military training area. The other fatality of known cause was a nestling that was found buried in a collapsed rodent burrow underneath the nest. The only fatality detected after dispersal was located 19.5 km north of its natal territory. The radio transmitter, attached leg, and a few feathers were found near a large steel electrical power

transmission tower. It was classified as unknown since the condition of the remains could have been caused by predation or scavenging. The three remaining carcasses were recovered at 100, 10, and 1 m from their respective nest scrapes, all having died of unknown causes. No other owls were located after dispersing from their natal territory. Adult owls left their breeding territory on approximately the same day as the youngest fledgling left.

A survivorship curve for fledgling short-eared owls is shown in Fig. 1. Fifteen of 17 fatalities (88.2%) occurred prior to or at the earliest fledging age (25 d post-hatching). The youngest fledgling I observed flying was 29 d post-hatching and the oldest fledgling that did not flush when closely approached was 34 d post-hatching.

A parametric regression model of survival created using SAS® proc LIFEREG showed hatch date has a significant negative effect on fledgling survival ($\chi^2 = 4.44$, df = 1, $\underline{P} = 0.04$). The model results predict that for each day into the season an owl hatches, it experiences a 3% decrease in expected survival time. The age at which a nestling was instrumented did not have a significant effect on expected survival time ($\chi^2 = 0.87$, df = 1, $\underline{P} = 0.35$).

Survival results separated by nesting territories are shown in Table 2. A nonparametric Wilcoxon test of a null hypothesis of equality of survival functions over nest

territories was significant (χ^2 = 18.6, df = 6, $\underline{P}$ =0.005), indicating the probability of survival for fledglings varied among sampled nest territories. A linear regression of brood size at 12 d post-hatching to brood size at 20 d post-hatching was significant (r^2 = 0.31, $F_{(1,23)}$ = 10.28, $\underline{P}$ = 0.004, Appendix, Table A2).

The mean cover value, measured by a coverboard, for 11 nests is 39.4 squares (10 cm^2) obscured, which differs significantly from the mean cover value of 7.36 squares for 11 points selected randomly throughout the study area (t = 9.74, df = 20, $\underline{P}$ = 0.0001). Fledgling survival time regressed against average cover was not significant (χ^2 = 1.7, df = 1, $\underline{P}$ = 0.19). Collection of habitat and vegetation parameters was limited to only three nesting territories due to fires and logistical problems. All habitat regressions versus survival were not significant, although the small sample sizes provided little power for these analyses (all $P_{values} > 0.39$).

DISCUSSION

The survival of fledgling short-eared owls reported here is lower than the survival rates reported for most other owl species. Marks (1986) reported 86 to 96% of long-eared owl (Asio otus) fledglings survived the 2-week period between leaving the nest and first flight in the same study

area. Great horned owl (Bubo virginianus) fledgling survival rates from banding to independence varied from 80% during good prey years to 23.2% during low prey years (Rohner and Hunter 1996). In eastern screech owls (Otus asio) in central Kentucky, 81.8% of the fledglings survived (Belthoff and Ritchison 1989). In contrast, Petty and Thirgood (1989) reported only 8% of tawny owl (Strix aluco) fledglings survived. Of these species, only the short-eared owl is a ground nester with the accompanying greater potential for predation of nestlings and fledglings (Ricklefs 1973).

In my study, short-eared owl fledgling mortality occurred primarily prior to the earliest age of first flight (25 d post-hatching) with 88.2% of all mortality occurring during this period. Most earlier studies of fledgling survival report predation as the main cause of mortality (Belthoff and Ritchison 1989, Sullivan 1989, McFadzen and Marzluff 1996, Rohner and Hunter 1996, Anders et al. 1997). Short-eared owls, being ground nesters, would be expected to have higher losses to predation than aboveground nesters. However, my results show that relatively few of the deaths (29.4%, n = 5) can be attributed to predation. The fatalities attributed to predation occurred prior to the earliest age of first flight. With the exception of the remains of the dispersed short-eared owl found beneath a

steel electrical power transmission tower and a fatality at ISA transect 792, either due to an unknown predator or scavenged following death from another cause, none of the other mortalities of unknown cause (n = 2) could be the result of predation as the carcasses were found intact in the vicinity of the nest, with no apparent injuries. It is interesting to note that no cases of avian predation on short-eared owl fledglings were observed in this study area even though this area has one of the highest raptor breeding populations in North America (U.S. Dept. of Interior 1979). Adult short-eared owls chased diurnal raptors such as prairie falcons (Falco mexicanus), golden eagles (Aquila chrysaetos), and northern harriers (Circus cyaneus) from nesting territories. Additionally, none of the short-eared owl nesting territories were located near great horned owl nesting territories. Coyotes (Canis latrans) were a more persistent predator, seen on several occasions hunting within short-eared owl nesting territories, and appeared undisturbed by stooping adult short-eared owls.

Given the limited sample size of this study, it is difficult to assess the significance of the other leading causes of mortality: starvation and heat stress. Both were single events: the disappearance of the adult female, in the case of the starved brood, and a hot day with little available cover, in the case of the heat stress fatalities.

The effect of hatch date on fledgling survival and breeding success varies among species and locations. Some studies report no significant correlations (McFadzen and Marzluff 1996, Anders et al. 1997). Harris et al. (1992) reported a negative correlation of hatch date on post-fledgling survival of guillemots (Uria aalge) during years of high fledgling survival but not in years of lower fledgling survival. In Ural owls (Strix uralensis) a negative correlation was found between hatching date and the breeding success and survival of fledglings (Saurola 1989). Decreased survival of fledglings and juvenile birds with delayed hatching dates is often attributed to the lack of time to develop foraging skills prior to the onset of winter and diminishing food supplies late in the breeding season. In this study, I suggest that the seasonal decline in the survival of fledgling short-eared owls is due in part to increased daytime temperatures late in the nesting season. This study site is near the southern edge of the breeding range of short-eared owls (Holt and Leasure 1993). While only two fatalities directly implicated heat stress, other signs of heat stress may have been more subtle. All of the nestlings in the Sand Creek N brood (the last brood to hatch) grew slowly during the nestling period even though excess food was usually present in the nest. Heat stress has been a significant cause of mortality for nestling

golden eagles in the same study area (Beecham and Kochert 1975).

The inequality of survival among nesting territories is consistent with avian lifetime reproductive success studies in which the majority of offspring recruited into the breeding population are produced by a small portion of the breeding population (Newton 1989). However, single events such as loss of the adult female may bias the results in a small sample such as presented here. It is worth noting that all broods had at least one fatality.

The significant correlation of brood size at 12 d post-hatching to brood size at 20 d post-hatching could be viewed as validating the use of survival at 12 d post-hatching to estimate fledgling success. However, with the low r^2, the model provides little predictive power.

A frequent concern of nesting success and fledgling survival studies is that the investigator induced error either through negative effects of attached radio transmitters (Gessaman and Nagy 1988, Paton et al. 1991, Foster et al. 1992) or human visits to nests and nestling handling stress (Fyfe and Olendorff 1976, Taylor 1991). Heavier backpack-mounted radio transmitters have been shown, under some conditions, to lower both adult survival and reproductive success in spotted owls (Strix occidentalis, Paton et al. 1991, Foster et al. 1992). Other studies with

both backpack-mounted (Vekasy et al. 1996) and lighter tail- or tarsal-mounted transmitters (Sodhi et al. 1991, Taylor 1991) have found no effect on nesting success or survival. Collection of mortality data on short-eared owl fledglings would have been impossible without instrumentation because they hide in the shrub steppe vegetation. I believe the radio transmitters had no observed effects on the survival of short-eared owl fledglings in this study since the age at which a nestling was instrumented did not significantly correlate with survival. If radio transmitters had a deleterious effect, nestlings instrumented at a younger age could be expected to have slightly lower survival than those instrumented at an older age. Additionally, the relatively low rate of predation in this study suggests that predators following investigators to nests and fledglings was not a major factor during the study period. A larger sample size would be needed to assess more subtle effects of investigator disturbance and radio transmitters on fledgling survival.

This study has shown that short-eared owl fledglings experience relatively low survival prior to independence due to a variety of causes, with all broods experiencing some losses. Broods hatching later in the summer experience lower survival possibly due to higher summer temperatures. Brood counts at 12 d of age are a significant but imprecise

predictor of reproductive success measured in terms of number of fledglings to disperse.

Many unresolved questions should be addressed before meaningful management plans for this sensitive species can be created. What is the year-to-year variation in fledgling survival? What effect do prey levels and habitat structure have on reproductive success and fledgling survival? Are short-eared owl populations within this widespread shrub steppe habitat sinks or sources for populations in other habitats? Another concern is the nomadic behavior of short-eared owls, potentially breeding in different areas in subsequent years resulting in an apparent inflation of the total population size as determined by short-term studies. Further study is necessary to resolve the population dynamics of the short-eared owl in the western United States. While it is possible to detect short-eared owl fledglings without radio transmitters at dusk by listening for food begging calls or observing them harassing adult owls for food, many fledglings would go undetected, causing an underestimation of reproductive success. This study has shown that radio telemetry of fledgling short-eared owls is a viable and useful technique for determining fledgling survival.

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Table 2. Short-eared owl fledgling mortality by nesting territory.

Nesting territory (Year)	Number instrumented	Number dispersed	Causes of Mortality
Artillery Range (1994)	3	3[a]	Unknown(1)
Christmastime (1994)	4	0	Starvation(4)
ISA Transect 792 (1994)	2	1	Unknown(1)[b]
Poen Road West (1994)	4	2	Heat Stress(2)
Sand Creek North (1994)	4	0	Mam. Pred.(2), buried(1),unknown(1)
Range 14N (1993)	2[c]	1	Unknown(1)
Wind Butte (1994)	6	2	Mam. Pred.(2), vehicle (1)

[a] One dispersed fledgling remains were found under a electrical power transmission tower

[b] Unknown, possible predation or scavenged

[c] One nestling was found dead at 15 days post-hatching prior to being instrumented

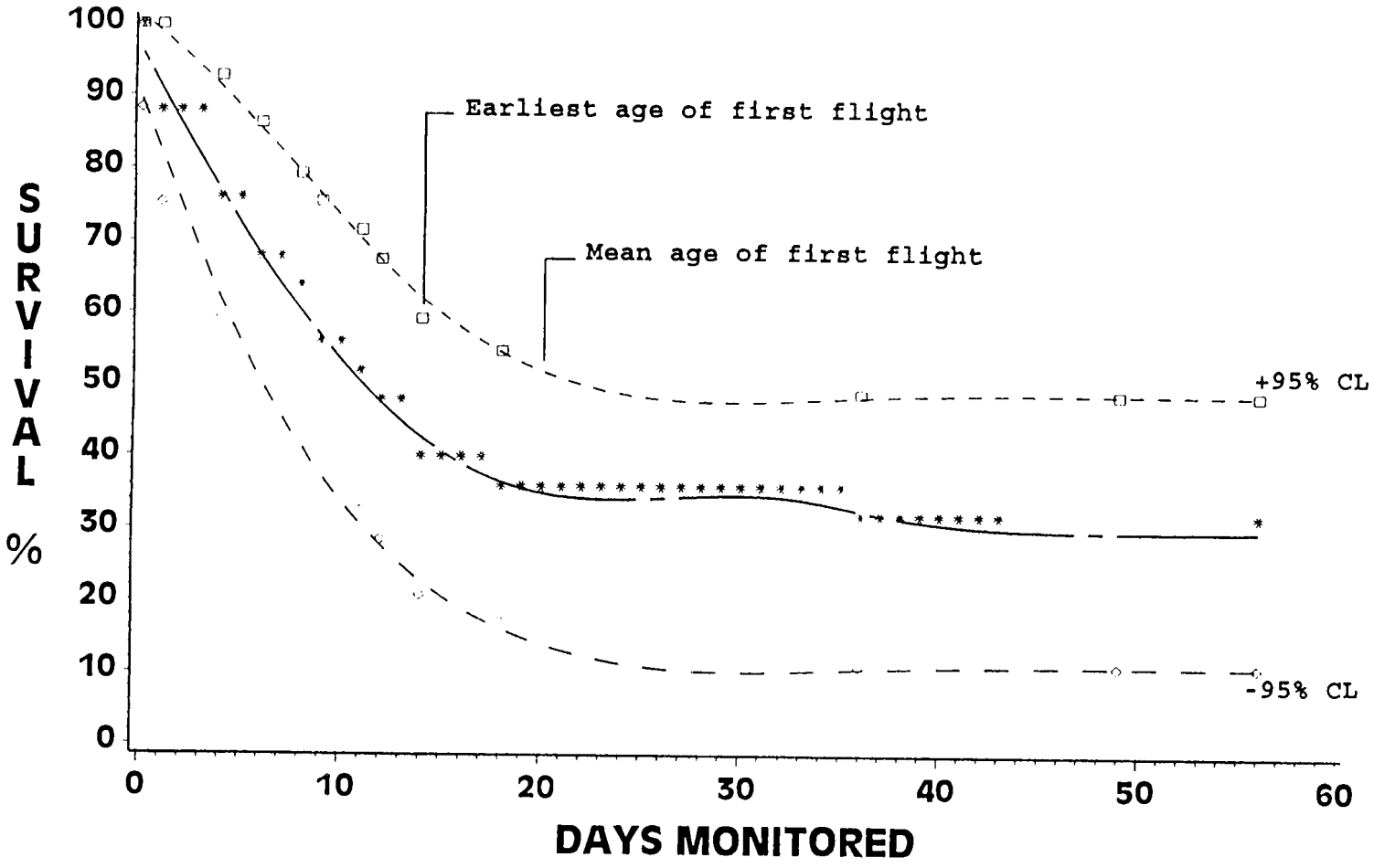

Figure 1. Survival of fledgling short-eared owls versus days monitored.

CHAPTER IV

A MIST NET TRAP FOR CAPTURING BREEDING SHORT-EARED OWLS

Radio-telemetry studies of breeding raptors require a reliable, safe, and low cost technique for capturing adult raptors. Adult short-eared owls (Asio flammeus), especially males, have proven difficult to trap (Leasure and Holt 1991). Mist nets have been lowered over brooding female short-eared owls to capture them on their nest with good results (Leasure and Holt 1991). Noose carpets, bal-chatri traps, and mist nets have been used to capture short-eared owls, but either no published success data are available (Bloom 1987) or the success rate was low (Kahn and Millsap 1978). Additionally, these techniques can be labor intensive, requiring construction of many traps and extensive waiting periods to allow short-eared owls time to discover the traps.

Dho-gaza traps accompanied by a great horned owl (Bubo virginianus) serving as a lure have been shown to be effective in capturing numerous diurnal and nocturnal raptor species (Hamerstrom 1963, Bloom et al. 1992). Most of Hamerstrom's work involved capturing northern harriers (Circus cyaneus); however, four short-eared owls were caught using the same trap. I used a non-detachable mist net trap arranged and baited as a traditional dho-gaza trap to

capture breeding short-eared owls in southwestern Idaho during 1994.

METHODS

Traditional dho-gaza traps consist of a piece of mist or gill net that detaches from supporting poles upon impact and collapses around the raptor. I used a standard 2.1 X 5.5 m mist net (10 cm mesh, 2 ply, 210 denier; Avinet Inc., Dryden, NY) that did not detach from supporting poles similar to mist net traps used by others (Bloom et al. 1992, Ulmschneider 1992, Steenhof et al. 1994). A non-detachable mist net can be used over shrubsteppe vegetation without having to remove vegetation from the trap site to prevent net damage. For the first eight trials and one trial later in the season I used a single net arrangement with a plastic great horned owl lure (Cabela's, Sidney, NE). The plastic owl lure was mounted on a pole 1.5 m above the ground with the mist net 1 m behind the lure, extending 1 m above and below the lure. The mist net trap was placed within the nesting territory of short-eared owls, between 100 m and 250 m from the nest if the nest location was known. Trapping was done after dark once the last glow on the horizon was completely gone. The trap required about 50 min to set up. An observer watched the trap using AN/PVS-7B night vision goggles. The observer remained underneath a 1.1 X 2.2 m piece of tan camouflage patterned fabric at a distance of

approximately 21 m from the trap. At this distance the lure owl and approaching short-eared owls were clearly visible with the night vision goggles but the net was barely visible. After the first trial, a recording of a great horned owl was played through a speaker mounted beneath the lure owl to reduce short-eared owl response time.

In an effort to improve trap efficiency, 16 of the final 17 attempts used a two-net arrangement with the nets forming a V when seen from above. The lure owl was placed in the center of the V. During seven of these attempts a live great horned owl replaced the plastic lure owl. The live lure owl was tethered through a swivel to a platform attached to the top of the lure post and could not reach the edge of the platform.

In accordance with Bloom et al. (1992), I report trapping success as number captured divided by number of captures possible. In contrast to Bloom et al. (1992), I took the trap down after catching one member of the pair, so capturing the second member was not a possibility. I also report the escape rate as the number of owls that contacted the net but were not captured divided by the number of owls contacting the net. This later measure gives an indication of how frequently owls hit the net and bounced out.

RESULTS AND DISCUSSION

Seven adult short-eared owls, four males and three females, were captured during 25 attempts for an overall trapping success of 28%. Ten adult owls contacted the nets during trapping, yielding an escape rate of 30%. The trap was set for a total of 48.6 hr, yielding 0.144 owls per hour trapping effort. The seven successful attempts took 11.2 hr, yielding a mean capture time of 1.6 hr (range = 0.33 to 6.5 hr, SD = 2.24 hr).

During one capture, the short-eared owl dropped into the vegetation while in the net and remained there undetected for an unknown time. After that capture, small bells were attached to mist net trammel lines to give an audible notice of owls contacting the net. If that attempt is removed from the calculation of mean capture times, the mean capture time drops to 0.79 hr (47 min, Range = 0.33 to 1.083 hr, SD = 0.66 hr).

Observations of short-eared owl behavior around the trap using night vision goggles revealed that under certain weather conditions such as overcast skies, moonlight, or wind speeds greater than a slight breeze, short-eared owls successfully avoided the net. Five trapping attempts were made during such unsuitable weather conditions. If those attempts are discarded, the territory trapping success rises

to 35% and owls per hour trapping effort improves to 0.21 owls per hour trapping. The escape rate remains unchanged.

For comparisons of trap effectiveness among the various trap configurations, I dropped the attempts made during unsuitable weather from the sample, leaving 20 attempts in the sample. Although short-eared owls appeared to be more aggressive toward a live lure owl than a plastic lure, there was no significant difference between the two lures in terms of captures per attempts (χ^2 = 0.037, $\underline{P}$ = 0.848). The plastic lure resulted in four captures (33.3%) in 12 attempts and the live owl lure was responsible for three captures (37.5%) in eight attempts. There may also be a temporal bias in the capture data as the live owl lure was used later in the season when more pairs may have been caring for fledglings. In trapping other raptor species with similar traps, trapping success decreases as the young age (Bloom et al. 1992). Contrary to expectations, the single net arrangement had a higher success rate with four captures (66.7%) in six attempts compared to three captures (21.4%) in 14 attempts with two nets. This difference was nearly significant (χ^2 = 0.3.78, $\underline{P}$ = 0.052). Further study is needed with a larger sample size to verify these trends.

The addition of a recording of a great horned owl appeared to decrease the time required for the resident short-eared owls to respond to the lure. The owls generally

approached the trap within 10 min of the start of the playback, whereas during the first trial without playback it took about 2 hr for the owl to approach the trap. If the resident short-eared owl did not respond by stooping at the owl lure, capture was unlikely. Individuals varied in their response to the trap. Some short-eared owls only vocalized and wing-clapped around the trap, whereas others repeatedly struck the net, before finally being captured. Some short-eared owls even struck the plastic lure owl several times before becoming tangled in the net. No short-eared owls ever made contact with the live lure owl. Many short-eared owls approach the net slowly and easily bounce out of the net, so it is important that the net be loose enough to prevent the owl from pushing off the net with its wings.

The mist net trap was reasonably effective in capturing both male and female adult short-eared owls during the breeding season with a trapping success of 35% after excluding attempts made during unsuitable weather. Additionally, some trapping attempts were made without knowledge of the reproductive status of target owl or actual nest location. These birds may have already failed in their breeding attempt and thus have had a reduced response to the lure owl. Success may be improved by placing the trap closer to the nests as some researchers have done with other species (Bloom et al. 1992). However, the increased

disturbance, not just from the trapping period but trap setup and removal, should be carefully considered. Only one nontarget species, a long-eared owl (Asio otus), approached and stooped the lure but was not caught.

This work has shown the mist net trap to be a useful method for capturing breeding adult short-eared owls. The single net with plastic lure owl arrangement is very quick and inexpensive. If night vision goggles are not available, the trap could be left unattended with a plastic owl lure and checked at 45-min intervals, although the risk of predation on captured owls by great horned owls or mammals should be considered. A mist net trap with a live lure owl should not be left unattended due to the risk of injury to both lure and target owls.

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CHAPTER V

SUMMARY

I examined two aspects of short-eared owl breeding ecology in a xeric shrubsteppe habitat: breeding season diet, and post-fledgling mortality prior to dispersal from the natal area. In support of other short-eared owl diet studies, I found the breeding season diet to be almost exclusively composed of small rodents. The breeding season diet was similar to the diet of the congeneric long-eared owl in the same study area. However, the diet of this population of short-eared owls, rather than being dominated by a single prey species as was reported in other short-eared owl studies, is split among four rodent species. This resulted in the largest reported Food Niche Breadth for a short-eared owl diet composed of primarily mammalian prey.

I found a significant shift in short-eared owl prey proportions between 1993 and 1994. This is likely the result of a shift in the relative population sizes of the four most common prey species between the 2 years. After pooling diet samples from both years, a significant shift in prey proportions was observed between nesting sites within 500 m of irrigated agricultural land and those farther than 500 m from irrigated agricultural land. This is likely due to changes in individual prey species abundance in the mesic irrigated land versus xeric shrubsteppe habitat.

In this study I found short-eared owl post-fledgling survival to be lower than post-fledgling survival reported for other owl species. Most of the mortality occurred prior to the age of first flight. The causes of mortality were varied, with mammalian predation and starvation being responsible for approximately one half of the fatalities. Mortality due to mammalian predation was lower than that reported by other studies. Interestingly, no avian predation was observed in a study area hosting one of the highest raptor breeding populations in North America.

Like other studies of post-fledgling survival, I found a significant negative correlation between post-fledgling survival and hatch date. While other studies attribute this correlation to lack of time to develop foraging skills prior to the onset of winter, in this study area it is possibly due to increased daytime temperature late in the nesting season. While a significant correlation of brood size at 12 d post-hatching and brood size at 20 d post-hatching was found, it lacks predictive power and thus brood counts at the former age is not a good predictor of nesting success. However, given the sample size constraints of this study, further work may elucidate a predictive relationship between brood counts in the nest and brood counts at first flight.

I applied a mist net raptor capture technique to breeding short-eared owls. While overall capture success

was moderate, many early attempts reflect my unrefined technique and may not be representative of the potential of this technique with this species.

This research is the first to examine short-eared owl post-fledgling survival and short-eared owl diet in a xeric shrubsteppe habitat. Although sample size constraints limit these results, they are an important first look at two unstudied aspects of this difficult-to-study species.

APPENDIX

STATISTICAL ANALYSES

Table A1. Prey/pellet among samples: ANOVA

SOURCE	SS	DF	MS	F	P
PREY/PELLET	65.6	2	32.8	23.3	0.0001
ERROR	356.4	253	1.41		

Table A2. 12 d post-hatch to 20 d post-hatch linear regression.

SOURCE	SS	DF	MS	F	P
MODEL	14.1	1	14.1	10.3	0.004
ERROR	31.6	23	1.37		